A PROPOSED APPROACH TO TARGET TEMPERATURE DEVELOPMENT FOR THE COLUMBIA RIVER TMDL

Richard B. Parkin[1]

ABSTRACT

A proposed approach for the development of target temperatures for the Columbia River Temperature TMDL is described. The target temperatures are based on the site potential temperatures for the river. The water quality standards for temperature in the lower reach of the Columbia River are the most restrictive and serve as the basis for the TMDL. Temperature in the upper reaches must be restricted to less than that allowed by the water quality standards for those reaches. A proposal for establishing target temperatures for the river reaches is described.

INTRODUCTION

This paper discusses an approach for the development of temperature targets which is under consideration in the development of a proposed temperature TMDL for the Columbia River . This TMDL is part of a larger effort, still under development, to establish a Temperature TMDL for the Columbia and Lower Snake River main stems. This paper, therefore is preliminary in nature; its substance subject to revision as the TMDL project moves forward.

The scope of the Columbia River TMDL is water temperature in the main stem segments of the Columbia River from the Canadian Border to the Pacific Ocean. This TMDL addresses dams and point sources of thermal loading to the main stem. There are 11 dams and 77 point sources on the Columbia River addressed by this TMDL.

APPLICABLE WATER QUALITY STANDARDS

Two states and one Indian tribe have water quality standards (WQS) promulgated pursuant to section 303(c) of the CWA that apply to the Columbia River: Oregon, Washington and the Confederated Tribes of the Colville Reservation. Another Indian tribe, the Spokane Tribe of Indians has WQS for the Columbia River that have been adopted by the tribe but not yet approved by EPA. Table 1 summarizes the WQS that apply along the Columbia River. The table includes the most stringent standard that applies for each reach.

---

1 Ecologist, U.S. Environmental Protection Agency, Region 10,
1200 Sixth Ave, Seattle, WA 98101

Table 1. Summary of Water Quality Standards that Apply to the Columbia River

River Reach	Criterion	Natural Temp < Criterion	Natural Temp > Criterion
Canadian Border to Grand Coulee Dam	16 °C	Natural + 23/(T+5)	Natural + 0.3 °C
Grand Coulee Dam to Chief Joseph Dam	16 °C	Natural + 23/(T+5)	Natural + 0.3 °C
Chief Joseph Dam to Priest Rapids Dam	18 °C	Natural + 28/(T+7)	Natural + 0.3 °C
Priest Rapids Dam to Oregon Border	20 °C	Natural + 34/(T+9)	Natural + 0.3 °C
Oregon Border to Mouth	20 °C 12.8 °C*	Natural + 1.1 °C	Natural + 0.14°C

T = the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.
* From October 1 through June 30

The WQS for Oregon are established in the Oregon Administrative Rules, OAR 340-041-0001 to OAR 340-041-00975, “State-Wide Water Quality Management Plan; Beneficial Uses, Policies, Standards, and Treatment Criteria for Oregon.” The segment of the Columbia River which serves as the OR/WA border is included in this TMDL and subject to OR WQS. It stretches from the mouth of the river to river mile 309. Under the Oregon standard “ no measurable surface water temperature increase resulting from anthropogenic activities is allowed:..
ii) in the Columbia River ... when surface water temperatures exceed 68.0 ^{o}F (20.0 ^{o}C).
iii) in waters and periods of the year determined ... to support native salmonid spawning, egg incubation, and fry emergence ... which exceeds 55 °F (12.8 °C).
vi) in stream segments containing federally listed Threatened and Endangered species....” (OAR 340-41-0725(2)(b)(A).

The numeric temperature criteria are measured as the seven-day moving average of the daily maximum temperatures. If there is insufficient data to establish a seven-day average of maximum temperatures, the numeric criterion is applied as an instantaneous maximum. A measurable surface water increase is defined as 0.25 ºF (0.14 ºC). Anthropogenic is defined to mean that which results from human activity. The period of the year designated for the protection of salmonid spawning, egg incubation and fry emergence in the Columbia River is October 1 through June 30.

The WQS for Washington are established in the Washington Administrative Code, Chapter 173-201A WAC, "Water Quality Standards for Surface Waters of the State of Washington." In the WQS, the Columbia River is divided into 4 reaches (above Grand Coulee Dam, Grand Coulee Dam to Priest Rapids Dam, Priest Rapids Dam to The Oregon Border and along the Oregon Border) each with its own standard. The standard for each reach prohibits temperature over specified criteria due to human activity. The standards specify allowable increases in temperature when natural temperature is less than the criteria and when it is greater than the criteria as shown in Table 1. In the lower reach along the Oregon/Washington Border, Washington's standard applies when natural temperatures are lower than the criterion of 20 °C but Oregon's standard applies when natural temperatures are above the criterion.

The WQS for the Confederated Tribes of the Colville Reservation were promulgated by EPA at 40 CFR 131.135. These standards apply to the Columbia River from the northern boundary of the reservation (approximately river mile 721) downstream to Wells Dam (river mile 515). The Colville and Washington standards both apply from the northern boundary of the reservation to Wells Dam because the reservation extends to the center of the river for that length. The Tribe and State, therefore share jurisdiction for WQS on the Columbia River. The Colville and State standards are identical for the reach above Grand Coulee and for the reach between Chief Joseph Dam and Wells Dam. However for the reach between Grand Coulee Dam and Chief Joseph Dam, the Tribe adopted the more restrictive standard that applies above Grand Coulee Dam.

PROPOSAL FOR DEVELOPMENT OF TARGET TEMPERATURES FOR THE TMDL

The WQS that apply to the Columbia River require derivation of the specific target temperatures for the TMDL based on natural temperatures in the river. Natural temperature is considered to be the water temperature that would exist in the river in the absence of any human-caused pollution or alterations. It applies to all human activities: those that effect the river temperature directly such as point sources of warm water or dams and impoundments; and those that effect river temperature indirectly such as development in the water shed and air pollution that results in climate change.

The Columbia River was first dammed in 1938 and the Snake River, its principle tributary was dammed in the 19^{th} century. Since the 19^{th} century the watershed has been extensively developed for forestry, agriculture, mining and domestic and industrial uses. River temperature increases since the mid 1900's due to global warming have been documented in the Pacific Northwest (Foreman et al., 2001). There is little temperature data available for the free flowing Columbia and Snake rivers that would reflect natural temperature prior to the advent of these human sources of thermal energy in the watershed. Therefore, it is necessary to simulate natural temperatures in order to derive the specific temperature targets for the TMDL.

RBM 10, a one dimensional, energy budget mathematical model was developed to simulate temperature in the Columbia River (Yearsley, 2001). It simulates daily or hourly cross sectional average temperatures under conditions of gradually varied flow. Models of this type have been used to assess water temperature in the Columbia River system for a number of important environmental analyses. The Federal Water Pollution Control Administration (Yearsley, 1969) developed and applied a one-dimensional thermal energy budget model to the Columbia River as part of the Columbia River Thermal Effects Study. The Bonneville Power Administration et al. (1994) used HEC-5Q, a one dimensional water quality model, to provide the temperature assessment for the System Operation Review, and Normandeau Associates (1999) used a one-dimensional model to assess water quality conditions in the Lower Snake River for the U.S. Army Corps of Engineers. RBM 10 was used by the Corps of Engineers for the temperature assessment in the "Lower Snake River Juvenile Salmon Migration Feasibility Report and Environmental Impact Statement" (Corps, 2002).

RBM 10 requires information on the river system and weather. Necessary river system information includes topology, geometry (cross-sectional area and width), mainstem inflows and temperatures at the model boundary and tributary and point source flows and temperatures. In order to simulate temperature in the absence of human intervention, this information is needed for the original, free flowing river. Necessary weather information is cloud cover, dry bulb air temperature; wind speed, vapor pressure of the air and atmospheric pressure. A thirty year data record consisting of the needed weather and flow information was constructed for the period from 1970 through 1999. Stream geometry for the un-impounded and existing river was compiled from the Columbia River Thermal Effects Study (Yearsley, 1969), information from the Walla Walla District, U.S. Army Corps of Engineers and from NOAA navigation charts (Yearsley, 2001). Using this record, thirty years of river temperatures were simulated for both the existing impounded Columbia River and the free flowing river after the dams are mathematically removed.

Site Potential Temperature

This simulation strategy provides the temperatures that would occur in the Columbia River within the TMDL study area in the absence of human activity within the main stem of the river within the study area. These temperatures are referred to in the TMDL as site potential temperatures. As the name implies, they are the temperatures that could occur in the Columbia River within the TMDL study area if the influence of human activity in the main stems on water temperature is eliminated. The inputs to the model; main stem temperature and flow, tributary temperature and flow and weather are not natural conditions. Flows in the main stem and the tributaries have been permanently altered by the construction of dams. Weather in the basin has likely been permanently altered by climate change or global warming. In using actual temperature and flow in the tributaries and the main stem boundary condition and actual weather to simulate water temperature in the river in the absence of dams and point sources of warm water, we are simulating site potential temperatures as opposed to natural temperatures.

Figure 1 illustrates the site potential temperature and the actual temperature during 1977 at John Day Dam as simulated by the RBM10 model. The figure illustrates the typical differences between the site potential or free flowing river and the existing impounded river. The free flowing river tends to warm faster in the spring, but cool faster in the fall and winter. Temperature in the free flowing river also tends to vary more in response to changes in air temperature. Water temperature is not constant throughout the year. Neither is it constant from year to year or along the length of the river. There are warm years and cool years and the water tends to warm as it moves downstream. The estimates of site potential and ultimately the TMDL target temperatures have to account for that variation. The longitudinal variability is captured by dividing the river into a series of reaches and estimating the site potential at a target site in each reach. In this case, 15 reaches were designated, one for each dam in the river and four below Bonneville Dam. The Target site for each reach is in the tailrace of the dam at the foot of each reach. The yearly variability in site potential temperature was captured by simulating 30 years of site potential temperatures and computing the mean site potential temperature. Figure 2 illustrate the variability of site potential temperatures and the mean site potential at John Day Dam as simulated by RBM 10.

Target Temperatures

The temperature targets for the proposed TMDL are the mean site potential temperatures plus the incremental increases allowed by the WQS at each target site. These allowable increases vary with jurisdiction, location in the river and the site potential temperature. Where jurisdictions overlap, the allowable incremental increases in this TMDL are based on the more stringent WQS. Table 1 lists the allowable increases by river reach after accounting for differences between jurisdictions.

Figure 1. Simulated Site Potential and Existing Temperatures during 1977 at John Day Dam

The target temperatures are derived by adding the allowable increases to the mean site potential temperature. However, whenever the allowable increase in a river reach would result in exceedance of the water quality standards downstream of that reach, the target temperature has to be adjusted down so that it does not result in exceedance of down stream water quality standards. This actually is the case along most of the river. Most reaches cannot have the full incremental increase allowed by standards because they would cause exceedance of downstream standards. The water quality standards of the lowest reach on the river, along the Oregon/Washington border (see Table 1) limit the allowable increase in temperature in the rest of the Columbia River. The allowable temperature increases of the upstream reaches shown in Table 1 must all be adjusted down in order to meet the water quality standards of that down stream reach. Therefore, the allowable temperature increases actually must be allocated among the reaches.

Figure 2. Simulated Site Potential Temperature 1970-1999 and the 30 Year Mean Site Potential Temperature at John Day Dam

Before determining how to allocate the allowable temperature increases among the reaches we evaluated the relative effects of point sources and dams on water temperature. There are 15 dams and 106 point sources with individual permits on the Columbia and lower Snake rivers that potentially effect temperature on the Columbia. Figure 3 shows the 30 year mean simulated temperatures at Columbia river mile 42 for existing river conditions, conditions if the106 point sources were removed and conditions that would exist if the dams and point sources were removed.

In the figure, the top two curves representing existing conditions and conditions with point sources removed are indistinguishable. This demonstrates that the existing point source discharges have a very minor effect on temperature. The figure shows that the dams, on the other hand have a significant effect. Because of this, the TMDL team is considering allocation of temperature increases along the river to account for the existing point source discharges. That is, the TMDL would provide for the continued discharge of the existing point sources at their current thermal loads, to the extent possible.

This allocation scenario would require all of the necessary temperature improvement in the river to result from curtailing temperature increases caused by the existing dams. The dams would not be able to raise water temperature. This allocation of the entire allowable temperature increase to the point sources is reasonable in light of the great disparity in the relative impact of dams and point sources on temperature and the minuscule benefit that dams would receive from decreasing the thermal input of the point sources. Relative to the improvements required at the target sites, the benefits to the dams of reducing the thermal loads from point sources are very small. If the point sources are allowed no thermal load, the improvement to water quality is negligible as shown in figure 3.0. The improvement in water quality still needed by the dams to achieve water quality standards would be affected very little by removing the point source loads.

Therefore the proposal for developing target temperatures for the TMDL along the Columbia River is to allocate sufficient temperature increase in each reach to account for the existing point source discharges in the reach, to the extent possible.

Figure 3: Simulated 30 year mean water temperature at Columbia River mile 42: existing conditions, point sources removed and dams and point sources removed.

CONCLUSION

In this proposed approach, the target temperatures for the Columbia River temperature TMDL are first derived by adding incremental temperature increases prescribed by state water quality standards to the mean site potential temperature for each day of the year. However, water quality modeling reveals that this process will result in the exceedance of water quality standards for temperature in the down stream reach. In order to achieve water quality standards downstream, temperature in the upper reaches of the river must be restricted more than the water quality standards prescribe for those reaches. The proposed approach is to allocate sufficient temperature increase in each river reach to account for the existing point source discharges in the reach, to the extent possible. This approach would minimize the effect of the TMDL on point source discharges. The TMDL will require significant improvement in temperature as affected by the dams. But the approach to allocating all of the allowable increases to the point sources will have negligible affect on the temperature improvement required at the dams.

REFERENCES

Bonneville Power Administration et al. 1994. *Columbia River system operation review.* Appendix M, Water quality. DOE/EIS-0170. Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation, Portland, Oregon.

Code of Federal Regulations. 40 CFR 131.35 *Colville Confederated Tribes Indian reservation.*

Foreman, M.G.G., D.K. Lee, J. Morrison, S. Macdonald, D. Barnes and I.V Williams. 2001. *Simulations and Retrospective Analyses of Fraser Watershed Flows and Temperatures. Atmosphere-Ocean 39(2): 89-105*

Normandeau Associates. 1999. *Lower Snake River temperature and biological productivity modeling.* R-16031.007. Preliminary review draft. Prepared for the Department of the Army, Corps of Engineers, Walla Walla, Washington.

Oregon Administrative Rules, OAR 340-040-0001 to OAR 340-040-0210. *State-Wide Water Quality Management Plan, Beneficial Uses, Policies, Standards and Treatment Criteria for Oregon.* Washington Administrative Code Chapter 173-201A WAC, *Water Quality Standards for Surface Waters of the State of Washington.*

U.S. Army Corps of Engineers. 2002. Lower Snake River Juvenile Salmon Migration Feasibility Report and Final Environmental Impact Statement. Walla Walla, Washington.

Yearsley, J.R. 1969. *A mathematical model for predicting temperatures in rivers and river-run reservoirs.* Working Paper No. 65, Federal Water Pollution Control Agency, Portland, Oregon.

Yearsley, J. R. 2001. Application of a 1-D Heat Budget Model to the Columbia River System. US Environmental Protection Agency, Seattle, WA.